ANALYSIS OF IMPROVEMENTS IN SYSTEM EFFICIENCY AND SAFETY AT HIGHWAY-RAILROAD-PEDESTRIAN GRADE CROSSINGS

A Senior Honors Thesis

by

JONATHAN MICHAEL TYDLACKA

Submitted to the Office of Honors Programs
& Academic Scholarships
Texas A&M University
in partial fulfillment of the requirements of the

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Group: Engineering

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Approved as to style and content by:

Laurence R. Rilett
(Fellows Advisor)

Edward A. Funkhouser
(Executive Director)

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ABSTRACT

Analysis of Improvements in System Efficiency and Safety at Highway-Railroad-Pedestrian Grade Crossings. (April 2002)

Jonathan Michael Tydlacka
Department of Civil Engineering
Texas A&M University

Fellows Advisor: Dr. Laurence R. Rilett
Department of Civil Engineering

The purpose of this project was to perform micro-simulation analyses on intersections near Highway-Railroad Grade Crossings to determine if controlling mean train speed and train speed variability would improve safety and reduce delays. The first of two objectives for this project required the completion of a micro-simulation model and the subsequent checking of the model for errors and accuracy. The second part consisted of train speed sensitivity analyses on mean train speed and train speed variability.

A micro-simulation model of the Wellborn Corridor in College Station, Texas was created using VISSIM. The model was run ten times in each of the nine train speed distributions. Average delay was collected for each of the four intersections in the model. Additionally, the model was run with alternate train detection distances and select train speed distributions, and average delay was again collected.

For each train speed distribution and intersection, delays were compared using the t-test with a 95% confidence interval. Comparisons were made against train speed distributions with either the same mean speeds, the same standard deviations, the base train speed, or the same distribution with a different train detection distance. Furthermore, these comparisons were made for each of the four 10-minute intervals of the simulation.

Significant differences were found only in the second time interval, when the trains were present. Some significant differences were found when the mean train speeds were altered, and these

were more prevalent at the high volume intersection, George Bush Dr. However, the number of statistically different comparisons was still not considered substantial.

Ultimately, it was found that manipulating the train detection distance, the mean train speed, or the train speed standard deviation did not have a significant effect on the average delay for the traffic layout that was modeled for this particular corridor.

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INTRODUCTION

Intersections near Highway-Railroad Grade Crossings require special operating procedures in order to ensure that vehicles and pedestrians are not put at risk when trains are present. This is accomplished by traffic signal preemption. Traffic signal preemption basically entails four steps (1). First, the train is detected and the active railroad warning devices, consisting of gates and flashing lights, are initiated. Next, the right-of-way must be transferred from the current phase to the phase that controls the critical approach (e.g. where vehicles could potentially queue across the railroad tracks). This is defined as the "right-of-way transfer time". Third, this phase must have an adequate green clearance phase such that the tracks may be cleared. This is the "queue clearance time". Finally, there must be a "separation time" which is the amount of time the tracks are clear before the train arrives at the intersection. The main objective of signal preemption is safety. By law, the warning devices must provide a minimum of 20 seconds of warning time (2). Consequently, the sum of the three components listed above ("right-of-way transfer time", "queue clearance time", "separation time") must be less than or equal to 20 seconds during preemption.

Specifically, the current preemption strategies are designed to clear the tracks of all vehicle traffic before the train arrives at the intersection. Although safety is the main concern of preemption, the secondary objective of preemption is to minimize delay for the vehicles and pedestrians at the intersection. The current preemption techniques are designed for the fastest train and the train detector is placed based on the minimum 20 seconds of active warning time. This means that the detector is placed at the distance that the fastest train can travel in 20 seconds. Because the vast majority of trains travel at speeds slower than the fastest train, they will have warning times that are greater than the minimum 20 seconds. This extra warning time can have an adverse effect on the delay of the vehicles and pedestrians at the intersection.

Although current preemption techniques perform well in clearing the tracks of vehicular traffic, some inefficiencies still exist. Particularly, delays could be lowered for the vehicles at the intersections. While there have been a number of approaches for remedying this problem, they have all put the onus on traffic operations and management. In this project, the focus was on controlling the trains directly.

Scope

This project examined controlling certain train characteristics as a possible solution to the delay problem. Specifically, the project looked at the effect of controlling the mean train speed and the variance of train speed on vehicle delay. It should be noted that while the technology exists to control train speed directly, there is no law to allow this. However, this should not preclude examining this option. In fact, one could envision that the law might be changed if this option increases safety, reduces delay, and is cheaper than other alternatives. Ultimately, the hypothesis is that if the mean speed and speed variance of trains can be controlled, the system will be safer and more efficient.

In order to answer the hypothesis, the VISSIM 3.60 micro-simulation package was used to model the corridor. VISSIM was chosen because it can effectively simulate multi-modal systems, which, in this case, includes rail, vehicle, and pedestrian traffic.

The test bed for this project is the "Wellborn Corridor" in College Station, Texas. This corridor includes an urban arterial roadway, Wellborn Rd., which runs parallel to a single Union Pacific two-way railroad line. Both the road and tracks run through the campus of Texas A&M University, and there are a relatively large number of pedestrians and vehicles that cross the rail line at various highway-railroad at-grade crossings. In addition, there are approximately 15-20 trains per day using this corridor (3), and the number of traffic preemption events is relatively high. The section of interest will include four signalized intersections, each near a Highway-Railroad Grade Crossing, and they are (from north to south): Old Main Dr., Joe Routt Blvd., George Bush Dr., and Holleman Dr. See Figure 1 for a map of the corridor.

All work on this project was done using a micro-simulation model. Although some traffic data and other input values were collected, no other field data were collected. None of the results or strategies developed from this project were tested in the field.

Objectives

There were two objectives for this project. The first objective was to create a micro-simulation model of the Wellborn Rd. corridor that considers vehicle traffic, pedestrian traffic, and trains. After the creation of the model, the second objective was initiated. This entailed testing the hypothesis that by controlling train speed and train variance we can increase safety and reduce delays.

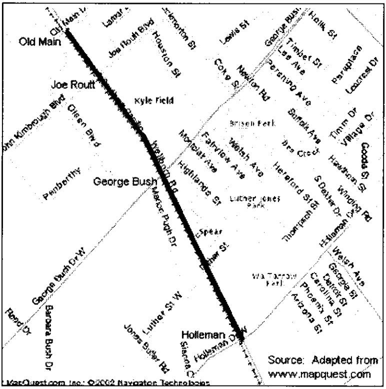

Figure 1. Map of Wellborn Corridor

METHODOLOGY

In order to create a working model in the VISSIM program, large amounts of field data, which included intersection layout, traffic volumes, and traffic signaling data, needed to be collected and compiled. Then, this data was coded into the VISSIM program to create the model for the corridor. This task included creating the layout for the model, inserting additional field data, and creating the traffic signaling files. The final task entailed running the VISSIM model to collect the traffic simulation data and then make changes to increase system efficiency and/or safety.

Intersection Layout

The intersection layout data was collected through the use of a Distance Measuring Instrument (DMI) in a TTI vehicle and through numerous site visits to the intersections. This data consisted of the following.

- Distance along Wellborn Rd.
- Length across the intersections
- Lane width
- Number of lanes and their configurations at each intersection
- Whether a turning bay was present, and, if present, its length

After this data was collected, some information was still missing. Due to the construction at the Joe Routt intersection, exact layout information was not available from the field at the time. Therefore, it was assumed that the intersection geometry would be as it was before the construction began. This data was found through old photos of the corridor as well as from a student's previous research project (4).

Traffic Volumes

The traffic volume data for this project came from a multitude of sources. Vehicle and pedestrian volumes were obtained for the George Bush and Old Main intersections from a traffic count done in September 2001 by the Texas A&M ITE Student Chapter. Their counts did not include the Holleman intersection, so the vehicle and pedestrian counts were taken for this project at the Holleman intersection on March 5, 2002. Unfortunately, the ITE counts were taken after construction had begun at the Joe Routt intersection, so the counts for this intersection were also lacking. Therefore, the traffic volumes for the Joe Routt intersection were found through the use of some older count data available from the City of College Station. Although the data for the Joe Routt intersection was about two or three years older than the other data, the volumes seemed to be reasonable, and they were deemed acceptable. All of the counts were taken during weekdays when the University classes were in session; therefore, the student population was near its peak. Although all of the counts included both AM and PM-peak volumes, this project looked only at the AM-peak period from 7:15-8:15. A figure of the AM-peak vehicle and pedestrian volumes used in the model can be found in Figure 2.

Traffic Signaling Data

In order to create the model to display the correct signaling, actual signal timings for the intersections would be needed. With the help of TTI researcher, Srinivasa Sunkari, the appropriate signaling data was collected from the City of College Station traffic-signal database. The signal timings were found for AM-peak, noon-peak, and PM-peak operations for each of the 4 intersections of concern; however, only the AM-peak timings were used for this project.

Coding Data into VISSIM

Intersection Layout

The creation of the VISSIM model began with the coding of the intersection layout. First, the lengths of the lanes, or "links" were created, and, then, the sections connecting the links at the intersections, or "connectors", were created as well. Finally, the railroad line was created as one link through the corridor.

During creation of the layout of the model, some generalizations were made about certain geometric aspects. Some basic generalizations about the specific lane geometry were also made. Although the actual lanes of Wellborn Rd. and the intersecting streets are not all of uniform width, every lane (including turning bays) was assumed to be 3.50 meters wide. This allowed for easier model creation and connectivity. Additionally, the actual left-turn bays are essentially continuous along Wellborn Rd., but this would not be feasible in the model. Instead, the lengths of the left-turn bays were shortened corresponding to the amount of use for each one. The lengths for the right-turn bays remained unchanged. The final geometric generalization involved the orientation of Wellborn Rd. with the railroad tracks. Although both of these do not run perfectly straight, it was assumed that Wellborn Rd. ran perfectly straight and that the railroad tracks ran parallel to the road. Since the tracks are offset from the road by 21.5 m at the Old Main and Joe Routt intersections and by 11.0 m at the George Bush intersection, the tracks curved slightly between the Joe Routt and George Bush intersections to accommodate this change.

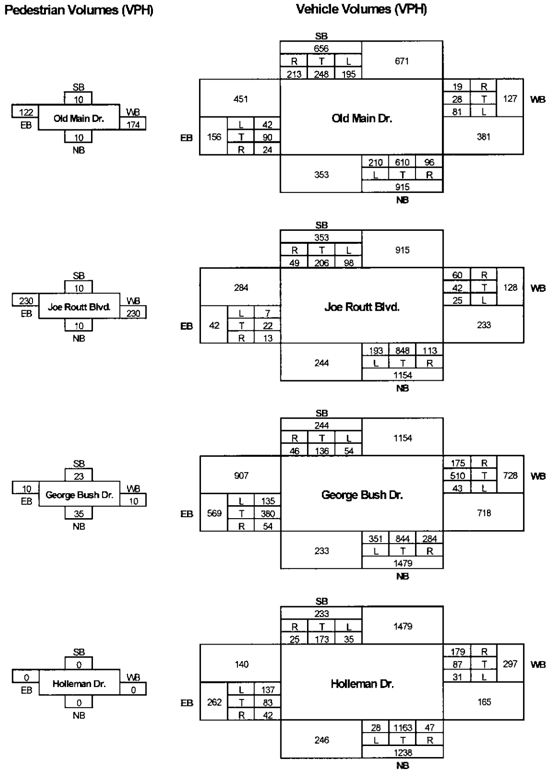

Figure 2. AM-peak Vehicle and Pedestrian Volumes

Traffic Volumes

Due to the construction at the Joe Routt intersection and the variety of sources for the volume data, the northbound outputs from the intersections did not match the northbound inputs at the next intersection to the north. This seems trivial because the only input volumes that were entered for Wellborn Rd. were the volumes for northbound vehicles at the Holleman intersection, those for the southbound vehicles at the Old Main intersection, and the side street volumes. Turning volume percentages were used for the northbound and southbound movements on the interior of the model. However, the actual volumes were used for all of the westbound and eastbound volumes.

In addition to the complexity added by the variety of sources for the volumes, some input errors were made with respect to the turning movement percentages. Although these errors were minor, they were not found until after the first set of runs was made, and they should be mentioned. The errors were caused by the fact that the data were collected at different times; therefore, the traffic volumes at adjacent intersections did not balance. The traffic volumes for north and south movements at adjacent intersections in the model were off by 7-9 % when compared to the actual counts, and a slight input error caused them to be off by another 1-2%. These errors are not thought to affect the results in any large amount for two reasons. First, for each of the ten runs made for each train speed distribution, VISSIM produced slightly different traffic volumes generated randomly for the intersections. Second, all of the results from this data are drawn from the comparison of the data generated from this model. Because these input errors were carried through the entire data collection process, the relative comparison of delays should not be adversely affected.

Traffic Signaling

For the traffic signal operation in the model, the vap logic file component of VISSIM was used instead of hardware-in-the-loop technology. The vap file method was chosen because, unlike hardware-in-the-loop, it allows a simulation to be run at various speeds faster than real-time. Because the goal was to run the simulation 10 times for each of the nine train speed distributions, this method would greatly shorten the data collection time for the project. Unfortunately, the creation of the vap files with preemption strategies proved to consume almost as much time as it saved.

Although all four of the intersections under consideration are operated in a coordinated mode in the field, for the purposes of this project, the signals in the model were operated in the actuated, free-running mode (without coordination). It was understood that this could cause the data to be somewhat skewed, but the time allotted for this project did not allow for the development of coordinated signaling logic with the corresponding railroad preemption logic. However, all of the other signaling data, including traffic actuation and pedestrian push button actuation, is the same as in the field. The signaling logic used for the George Bush Dr. is included, as an example, in Appendix C.

Additional VISSIM Inputs

The model was run ten times for each of the nine train speed distributions. The distributions were made up of three mean speeds (30, 40, and 50 km/h) each with three standard deviations (5, 10, and 15 km/h). Each run was for 2400 seconds, and the train was sent into the model at 600 seconds for every run. Additionally, the train length used for the model was 1184 meters, an average train length for the Wellborn Corridor.

The mean speeds and the standard deviations used for this model were based on the actual train speeds in the corridor, and the actual train data used for this project is shown in Figure 3. This histogram is from a graduate student's current work with the corridor, and it shows the average train speeds at the George Bush intersection.

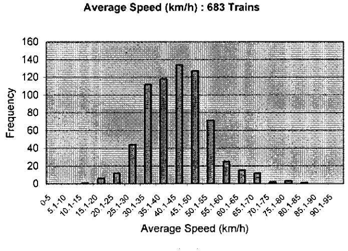

Figure 3. Actual Average Train Speeds at George Bush Dr.

The model was run ten times for each distribution using a train detection distance of 335 meters. This is based on the distance that a train traveling 60 km/h can travel in the required 20 seconds of warning time. Another set of runs were made in which the train detection distances were 280 meters and then 225 meters to detect trains traveling at 50 km/h and 40 km/h, respectively.

Collecting Data from VISSIM

The data collected from the runs included average vehicle delay, d_{ij}, for each movement at each intersection; however, this data was summarized to produce delay per intersection, d_j. The average delay for each intersection was found from Equation 1.

$$d_j = \frac{\sum_{i=1}^{N} V_{ij} d_{ij}}{\sum_{i=1}^{N} V_{ij}} \qquad \textbf{Eq. 1}$$

where

d_j = Average Delay at Intersection j
V_{ij} = Volume of Movement i at Intersection j
d_{ij} = Average Delay for Movement i at Intersection j
N = Number of Movements

Each distribution was run ten times for the 60 km/h train detection, and the distributions are as follows.

- 30 km/h mean with 5 km/h standard deviation
- 30 km/h mean with 10 km/h standard deviation
- 30 km/h mean with 15 km/h standard deviation
- 40 km/h mean with 5 km/h standard deviation
- 40 km/h mean with 10 km/h standard deviation
- 40 km/h mean with 15 km/h standard deviation
- 50 km/h mean with 5 km/h standard deviation
- 50 km/h mean with 10 km/h standard deviation
- 50 km/h mean with 15 km/h standard deviation
- 60 km/h mean with no deviation

Not all of the distributions were run for the other train detection distances. The 50 km/h train detection was run for only the following distributions.

- 30 km/h mean with 5 km/h standard deviation
- 30 km/h mean with 10 km/h standard deviation
- 40 km/h mean with 5 km/h standard deviation
- 50 km/h mean with no deviation

Finally, the 40 km/h train detection was run for only the 30 km/h mean with 5 km/h standard deviation and the base case of 40 km/h with no deviation.

RESULTS

Average delay was used as the main measure of effectiveness for this project. For each of the ten runs, average delay was collected for each intersection for each train speed distribution analyzed. Then, the ten runs were averaged, and five separate average delay times were found for each train speed distribution for the entire 40-minute period (one for each intersection and one average of the intersections). The summarized collected average delay data for the 40-minute period follows in Tables 1-3.

Table 1. Average Intersection Delay Times with 60 km/h Train Detection (seconds)

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds)				
	Old Main	**Joe Routt**	**George Bush**	**Holleman**	**Average**
(30 - 05)	29.3	23.1	41.0	28.6	32.0
(30 - 10)	28.8	24.2	42.4	28.2	32.6
(30 - 15)	30.5	25.4	40.7	29.4	32.8
(40 - 05)	26.5	23.5	38.0	27.4	30.2
(40 - 10)	27.8	22.9	37.2	26.2	29.8
(40 - 15)	27.3	23.0	38.4	28.2	30.6
(50 - 05)	25.0	23.4	35.6	26.3	28.7
(50 - 10)	26.3	22.7	35.0	26.2	28.6
(50 - 15)	26.7	23.3	35.4	26.3	29.0
(60 - 00)	26.6	21.8	37.9	26.5	29.6

Table 2. Average Intersection Delay Times with 50 km/h Train Detection (seconds)

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	29.2	24.0	39.6	27.8	31.5
(30 - 10)	29.6	24.1	40.0	28.2	31.9
(40 - 05)	27.7	23.2	37.8	26.4	30.1
(50 - 00)	24.9	22.4	37.7	25.9	29.3

Table 3. Average Intersection Delay Times with 40 km/h Train Detection (seconds)

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	28.9	23.0	40.1	27.4	31.4
(40 - 00)	26.8	21.9	40.1	27.3	30.6

Because the data showed a large amount of similarity when average delay was taken over the entire 40-minute simulation period, the average delay was then found at 10-minute intervals for each train speed distribution and for each intersection. As expected, it was found that the first and fourth 10-minute intervals showed a large amount of similarity because these were the times when the train was not present in the model. In addition, the third interval showed some similarity, but not as much as the first and fourth. This is because, for some of the runs with slower train speeds, the trains were still present in the early part of the third 10-minute interval.

However, the data from the second 10-minute interval showed some differences due to the fact that this was the interval that included the trains. Although the second interval appeared to show differences, the data still needed to be statistically tested to prove any significant differences. The summarized collected average delay data for the second 10-minute interval follows in Tables 4-6, and the data for each of the 10-minute intervals is found in Appendix A.

Table 4. Average Intersection Delay Times with 60 km/h Train Detection (seconds)
<u>Second 10-minute Interval</u>

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 660-1200 seconds (Second block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	38.1	29.1	55.1	31.2	40.3
(30 - 10)	39.1	31.8	52.2	29.5	39.7
(30 - 15)	37.0	32.1	46.5	29.2	37.3
(40 - 05)	31.9	31.0	43.1	30.8	35.3
(40 - 10)	33.2	26.7	47.3	30.0	36.1
(40 - 15)	34.0	31.0	47.1	32.9	37.7
(50 - 05)	30.2	26.4	44.2	30.1	34.3
(50 - 10)	30.9	25.5	43.0	30.3	33.8
(50 - 15)	34.0	25.1	43.3	29.0	34.3
(60 - 00)	30.5	23.9	48.8	27.2	34.8

Table 5. Average Intersection Delay Times with 50 km/h Train Detection (seconds)
<u>Second 10-minute Interval</u>

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 660-1200 seconds (Second block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	38.6	31.9	54.5	32.1	41.0
(30 - 10)	43.1	30.2	51.9	29.5	40.0
(40 - 05)	33.2	26.7	46.6	28.8	35.5
(50 - 00)	27.8	24.1	49.7	30.2	35.4

Table 6. Average Intersection Delay Times with 40 km/h Train Detection (seconds)
<u>Second 10-minute Interval</u>

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 660-1200 seconds (Second block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	39.8	28.6	55.4	30.5	40.4
(40 - 00)	31.8	26.1	47.2	29.7	35.5

CONCLUSIONS

Statistical Testing

In order to prove if any differences exist in the data, the t-test statistical test was used. First, for each train speed distribution, intersection, and 10-minute interval, the 95% confidence interval of the estimate was found for the corresponding average delay. Using the average delay, $\bar{x}$, and the standard deviation of the 10 runs, s, a range was found for each train speed distribution from Equation 2 (5).

$$\bar{x} \pm \frac{t_{\alpha/2,n-1} s}{\sqrt{n}} \qquad \textbf{Eq. 2}$$

where

$t_{\alpha/2,n-1}$ =	2.26, for 95% Confidence Interval
$\bar{x}$ =	Average Delay for Train Speed Distribution j
s =	Standard Deviation of Delay From 10 runs for Train Speed Distribution j
n =	Number of Simulation Runs, 10 for all cases

The confidence intervals were subsequently compared against each other. If any two ranges overlapped, the two distributions were not statistically different at the 95 % confidence interval. If the ranges did not overlap, the distributions were statistically different at the 95% confidence interval. The distributions are referenced in the following manner. The mean train speed of 30 km/h with a 5 km/h standard deviation for the 60 km/h train detection would be denoted as 60k 30-05, and the other distributions are noted similarly. The results from the statistical analysis are found in Appendix B.

Comparisons were made with distributions having the following characteristics.

- Same mean speed with same train detection distance
  Ex. (60k 30-05 with 60k 30-10)
- Same standard deviation with same train detection distance
  Ex. (60k 30-05 with 60k 40-05)
- Base mean speed (with no standard deviation) for the same train detection distance
  Ex. (60k 30-05 with 60k 60-00)

- Same mean speed and standard deviation with a different train detection distance
  Ex. (60k 30-05 with 50k 30-05)

Each distribution was compared to all other distributions with the same train detection distance and either the same mean speed, same standard deviation, or the base speed (with no standard deviation). Each distribution was also compared to the same distribution with a different train detection distance, if that distribution was used. Each comparison was done for all four intersections and for the average of the intersections, and the comparisons were divided into the four 10-minute intervals of the simulation.

As expected, no statistically different delays were found for the first 10-minute interval, and only three similarities were found in the third and fourth intervals (out of 630 comparisons). Therefore, it was hypothesized that in these time frames, the effect of the trains on traffic was negligible. This was confirmed visually.

For the second 10-minute interval, differences were found with the base mean speed; although, the differences were expected to be found in more than just 5 out of 65 comparisons.

Also, no differences were found for the same mean speed with different standard deviations. In general the delays rose with standard deviation as expected; however, there was no statistical difference. Since this was out of 120 comparisons, it was hypothesized that for this particular traffic setup, altering the standard deviations between 5, 10, and 15 km/h had no significant effect on the average delay.

Similarly, no cases showed a statistical difference for the same distribution with a different train detection distance. Again, the delay was expected to shorten as the train detection distance was lowered, but no significant difference was found.

The only meaningful differences appeared when the same standard deviations were used with different mean speeds at the same train detection distance. Comparing the data for each intersection and the average of the intersections, exactly 100 comparisons were made, and only 12 statistically different cases were found. However, if this data is compared for only the George Bush intersection, the result is 6 statistically different cases out of only 20 comparisons. This seems more substantial because the George Bush intersection is where the most traffic occurs; therefore, this is where one would expect the most significant impact on delay. Generally, delay decreased when the mean train speed increased, and the delays were shown to be statistically different in some of the comparisons.

Even though some statistically different cases were found for some cases involving different mean train speeds, the percentage of these cases was not high enough to be considered as showing a significant difference. Ultimately, it was found that manipulating the train detection distance, the mean train speed, or the train speed standard deviation did not have a significant effect on the average delay for the traffic layout that was modeled for this particular corridor.

Recommendations

One recommendation for future testing of this model would be to consider the pedestrian phasing during railroad preemption. During this project the number of times that pedestrian phases were truncated was not counted. Collecting this data would show to what degree pedestrian safety is compromised. Furthermore, this data could be compared to the delay data to possibly show that a tradeoff between the two exists.

Future testing of the model could also include using various larger and smaller traffic volumes to see the effect on the average delay. Sensitivity analyses could be performed to explore different train detection techniques as well as the number and length of the trains in the model. Another future test for the model could use emission data as a measure of effectiveness. Finally, the signal phasing could be updated to include coordinated signaling to again see the effect on average delay.

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APPENDIX A – SUMMARIZED DATA FROM SIMULATIONS

Average Intersection Delay Times with 60 km/h Train Detection (seconds)
First 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 0-600 seconds (First block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	26.4	19.8	27.7	23.6	25.0
(30 - 10)	27.2	20.1	28.1	24.0	25.5
(30 - 15)	26.4	19.8	27.7	23.6	25.0
(40 - 05)	25.5	19.2	26.9	23.1	24.2
(40 - 10)	25.2	19.4	27.7	23.6	24.7
(40 - 15)	26.7	19.0	26.2	22.6	24.1
(50 - 05)	26.4	19.8	27.7	23.6	25.0
(50 - 10)	26.4	19.8	27.7	23.6	25.0
(50 - 15)	26.5	20.7	27.5	23.3	25.0
(60 - 00)	25.6	20.3	28.9	24.9	25.7

Average Intersection Delay Times with 50 km/h Train Detection (seconds)
First 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 0-600 seconds (First block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	26.4	19.8	27.7	23.6	25.0
(30 - 10)	26.6	20.0	28.3	24.2	25.4
(40 - 05)	24.5	20.7	28.0	24.4	25.1
(50 - 00)	24.9	20.7	27.7	24.1	24.9

Average Intersection Delay Times with 40 km/h Train Detection (seconds)
First 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 0-600 seconds (First block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	26.3	19.4	28.5	23.9	25.3
(40 - 00)	26.8	21.0	28.0	23.9	25.5

Average Intersection Delay Times with 60 km/h Train Detection (seconds)
Second 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 660-1200 seconds (Second block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	38.1	29.1	55.1	31.2	40.3
(30 - 10)	39.1	31.8	52.2	29.5	39.7
(30 - 15)	37.0	32.1	46.5	29.2	37.3
(40 - 05)	31.9	31.0	43.1	30.8	35.3
(40 - 10)	33.2	26.7	47.3	30.0	36.1
(40 - 15)	34.0	31.0	47.1	32.9	37.7
(50 - 05)	30.2	26.4	44.2	30.1	34.3
(50 - 10)	30.9	25.5	43.0	30.3	33.8
(50 - 15)	34.0	25.1	43.3	29.0	34.3
(60 - 00)	30.5	23.9	48.8	27.2	34.8

Average Intersection Delay Times with 50 km/h Train Detection (seconds)
Second 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 660-1200 seconds (Second block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	38.6	31.9	54.5	32.1	41.0
(30 - 10)	43.1	30.2	51.9	29.5	40.0
(40 - 05)	33.2	26.7	46.6	28.8	35.5
(50 - 00)	27.8	24.1	49.7	30.2	35.4

Average Intersection Delay Times with 40 km/h Train Detection (seconds)
Second 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 660-1200 seconds (Second block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	39.8	28.6	55.4	30.5	40.4
(40 - 00)	31.8	26.1	47.2	29.7	35.5

Average Intersection Delay Times with 60 km/h Train Detection (seconds)
Third 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 1260-1800 seconds (Third block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	25.6	21.7	45.9	29.2	32.9
(30 - 10)	25.3	23.8	46.2	31.6	33.9
(30 - 15)	34.4	27.1	42.3	29.0	34.4
(40 - 05)	25.8	20.9	42.9	27.2	31.2
(40 - 10)	25.0	23.1	37.0	25.8	29.1
(40 - 15)	23.3	19.6	39.2	29.3	29.6
(50 - 05)	22.6	22.9	34.4	25.8	27.6
(50 - 10)	23.9	22.6	35.2	25.3	28.0
(50 - 15)	23.7	23.4	35.2	25.7	28.1
(60 - 00)	24.1	21.3	37.3	27.8	29.1

Average Intersection Delay Times with 50 km/h Train Detection (seconds)
Third 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 1260-1800 seconds (Third block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	25.8	22.1	39.9	28.2	30.7
(30 - 10)	25.6	21.6	44.0	32.5	33.1
(40 - 05)	26.4	21.2	38.5	26.5	29.7
(50 - 00)	23.5	21.3	36.0	24.3	27.8

Average Intersection Delay Times with 40 km/h Train Detection (seconds)
Third 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 1260-1800 seconds (Third block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	25.2	22.3	40.2	28.3	30.8
(40 - 00)	23.1	21.4	41.5	26.4	29.9

Average Intersection Delay Times with 60 km/h Train Detection (seconds)
Fourth 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 1860-2400 seconds (Fourth block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	27.4	22.2	35.2	29.5	29.6
(30 - 10)	24.3	20.9	41.9	27.2	30.6
(30 - 15)	24.0	22.0	44.4	34.8	33.5
(40 - 05)	22.9	21.9	37.5	27.7	29.0
(40 - 10)	27.4	21.7	35.8	25.1	28.8
(40 - 15)	25.8	22.4	39.1	27.3	30.2
(50 - 05)	21.9	23.7	35.1	25.3	27.7
(50 - 10)	24.4	22.2	33.2	25.0	27.1
(50 - 15)	23.0	23.5	34.4	26.6	28.0
(60 - 00)	26.0	21.3	35.0	25.7	28.2

Average Intersection Delay Times with 50 km/h Train Detection (seconds)
Fourth 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 1860-2400 seconds (Fourth block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	26.1	22.3	36.3	26.8	29.1
(30 - 10)	24.1	24.2	35.3	25.8	28.5
(40 - 05)	26.2	23.9	36.9	25.7	29.4
(50 - 00)	23.6	23.3	36.0	24.7	28.2

Average Intersection Delay Times with 40 km/h Train Detection (seconds)
Fourth 10-minute Interval

Train Speed (Mean – Std Dev) (km/h)	Average Intersection Delay (seconds) for 1860-2400 seconds (Fourth block)				
	Old Main	Joe Routt	George Bush	Holleman	Average
(30 - 05)	24.9	21.6	36.4	26.2	28.7
(40 - 00)	25.6	19.5	41.8	28.7	30.9

APPENDIX B – STATISTICAL ANALYSIS

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 30-05*** Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 30-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	60k 50-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	40k 30-05	0	0	0	0	0
660-1200 seconds	60k 30-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-05	0	0	1	0	1
	60k 50-05	0	0	1	0	1
	60k 60-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	40k 30-05	0	0	0	0	0
1260-1800 seconds	60k 30-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	60k 50-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	40k 30-05	0	0	0	0	0
1860-2400 seconds	60k 30-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	60k 50-05	1	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	40k 30-05	0	0	0	0	0

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 30-10*** Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 30-05	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 30-05	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 50-10	0	0	0	0	1
	60k 60-00	0	1	0	0	0
	50k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 30-05	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 30-05	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX

* Note: A train speed distribution of 60k 30-05 means that for the 60 km/h train detction, the trains had a mean speed of 30 km/h and a standard deviation of 5 km/h.

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 30-15*** Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 30-05	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 30-05	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 30-05	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 30-05	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 40-05*** Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 40-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	60k 50-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 40-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-05	0	0	1	0	0
	60k 50-05	0	0	0	0	0
	60k 60-00	0	1	0	0	0
	50k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 40-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	60k 50-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 40-10	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	60k 50-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	50k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 40-10***				
		Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 40-05	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 40-05	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 40-05	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 40-05	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 40-15***				
		Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 40-05	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 40-05	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 40-05	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 40-05	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 50-05***				
		Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 50-10	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 50-10	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-05	0	0	1	0	1
	60k 40-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 50-10	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 50-10	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Train Speed Distribution of Concern = **60k 50-10***				
		Old Main	Joe Routt	George Bush	Holleman	Average
0-600 seconds	60k 50-05	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 50-05	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-10	0	0	0	0	1
	60k 40-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 50-05	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 50-05	0	0	0	0	0
	60k 50-15	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	60k 40-10	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Old Main	Joe Routt	George Bush	Holleman	Average
		Train Speed Distribution of Concern = 60k 50-15*				
0-600 seconds	60k 50-05	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	60k 50-05	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	60k 50-05	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	60k 50-05	0	0	0	0	0
	60k 50-10	0	0	0	0	0
	60k 30-15	0	0	0	0	0
	60k 40-15	0	0	0	0	0
	60k 60-00	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Old Main	Joe Routt	George Bush	Holleman	Average
		Train Speed Distribution of Concern = 50k 30-05*				
0-600 seconds	50k 30-10	0	0	0	0	0
	50k 40-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	40k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	50k 30-10	0	0	0	0	0
	50k 40-05	0	0	1	0	1
	50k 50-00	0	0	0	0	0
	40k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	50k 30-10	0	0	0	0	0
	50k 40-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	40k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	50k 30-10	0	0	0	0	0
	50k 40-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	40k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Old Main	Joe Routt	George Bush	Holleman	Average
		Train Speed Distribution of Concern = 50k 30-10*				
0-600 seconds	50k 30-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	50k 30-05	0	0	0	0	0
	50k 50-00	1	0	0	0	0
	60k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	50k 30-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	50k 30-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	60k 30-10	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Old Main	Joe Routt	George Bush	Holleman	Average
		Train Speed Distribution of Concern = 50k 40-05*				
0-600 seconds	50k 30-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	50k 30-05	0	0	1	0	0
	50k 50-00	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	50k 30-05	0	0	0	0	1
	50k 50-00	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	50k 30-05	0	0	0	0	0
	50k 50-00	0	0	0	0	0
	60k 40-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

1=Statistically Different
0=Not Statistically Different

Simulation Time	Train Speed Distribution (For Comparison)	Old Main	Joe Routt	George Bush	Holleman	Average
		Train Speed Distribution of Concern = **40k 30-05'**				
0-600 seconds	40k 40-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
660-1200 seconds	40k 40-00	0	0	1	0	1
	50k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1260-1800 seconds	40k 40-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
1860-2400 seconds	40k 40-00	0	0	0	0	0
	50k 30-05	0	0	0	0	0
	60k 30-05	0	0	0	0	0
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX

APPENDIX C – VISSIM VAP SIGNALING LOGIC FOR GEORGE BUSH DR.

```
/****************************************************************************/
/******* FREE-RUNNING ACTUATED WITH PERMISSIVE LEFT-TURNS ********/
/******* WITH PEDESTRIANS ***********************************************/
/****************************************************************************/

/************************************************/
/***** GEORGE BUSH DR. AT WELLBORN RD. *****/
/************************************************/

PROGRAM SCJ3_Actuated_Free_Peds;

ARRAY
tamber[8] = [4,4,4,4,4,4,0,0],
Recall[8] = [0,1,0,0,0,1,0,0],
Passage[8] = [2,4.5,4,3,4,4.5,0,0],
MaxGreen[8] = [25,65,32,55,30,60,0,0],
MinGreen[8] = [7,10,8,8,7,10,0,0],
PedGreen[4] = [4,4,4,4],
PedClr[1] = [15],
RedClear[8] = [2,2,2,2,2,2,0,0],

/*** New Arrays ***/

PreempMin[1] = [5],
SelPedClr[1] = [15],
RetPedClr[1] = [15],
TrackClrTime[1] = [13],

DwellPedGreen[2] = [4,4],
DwellRECALL[6] = [0,0,0,0,1,1],
MinDwellGreen[6] = [0,0,0,0,10,60],
MaxDwellGreen[6] = [0,0,0,0,20,60];

/****************************************************************************/
/** Compute Conditionals ****************************************************/
/****************************************************************************/

SUBROUTINE Compute_Conditionals;

/*******************************/
/**** DEFINE CONDITIONALS ****/
/*******************************/

Call1 := presence(21) or occupancy(21) OR RECALL[1];
Call2 := presence(22) or occupancy(22) OR RECALL[2];
Call3 := presence(23) or occupancy(23) OR RECALL[3];
Call4 := presence(24) or occupancy(24) OR RECALL[4];
Call5 := presence(25) or occupancy(25) OR RECALL[5];
Call6 := presence(26) or occupancy(26) OR RECALL[6];

GapOut1 := headway(21) > Passage[1];
```

```
GapOut2 := headway(22) > Passage[2];
GapOut3 := headway(23) > Passage[3];
GapOut4 := headway(24) > Passage[4];
GapOut5 := headway(25) > Passage[5];
GapOut6 := headway(26) > Passage[6];

MinOver1 := t_green(1) >= MinGreen[1];
MinOver2 := t_green(2) >= MinGreen[2];
MinOver3 := t_green(3) >= MinGreen[3];
MinOver4 := t_green(4) >= MinGreen[4];
MinOver5 := t_green(5) >= MinGreen[5];
MinOver6 := t_green(6) >= MinGreen[6];

MaxOut1 := t_green(1) >= MaxGreen[1];
MaxOut2 := t_green(2) >= MaxGreen[2];
MaxOut3 := t_green(3) >= MaxGreen[3];
MaxOut4 := t_green(4) >= MaxGreen[4];
MaxOut5 := t_green(5) >= MaxGreen[5];
MaxOut6 := t_green(6) >= MaxGreen[6];

/****************************************/
/**** CONDITIONS TO CAUSE PHASES ****/
/**** TO CROSS BARRIER TOGETHER *****/
/****************************************/

GapOut26 := GapOut2 AND GapOut6;
MinOver26 := MinOver2 AND MinOver6;
MaxOut26 := MaxOut2 AND MaxOut6.

/********* FREE Actuated with Ped - Normal Mode ***************************/

/*************************************************************************/
/** CorrectionCompute_Conditionals ****************************************/
/*************************************************************************/

SUBROUTINE CorrectionCompute_Conditionals;

MinGreen[1] := 7;
MinGreen[5] := 7;

IF (FirstAfterDwell = 0) THEN
        FirstAfterDwell := 1;
END;

Recall[1] := 0;
Recall[2] := 1;
Recall[3] := 0;
Recall[4] := 0;
Recall[5] := 0;
Recall[6] := 1;

/********************************/
/**** DEFINE CONDITIONALS ****/
```

```
/*******************************/

Call1 := presence(21) or occupancy(21) OR RECALL[1];
Call2 := presence(22) or occupancy(22) OR RECALL[2];
Call3 := presence(23) or occupancy(23) OR RECALL[3];
Call4 := presence(24) or occupancy(24) OR RECALL[4];
Call5 := presence(25) or occupancy(25) OR RECALL[5];
Call6 := presence(26) or occupancy(26) OR RECALL[6];

GapOut1 := headway(21) > Passage[1];
GapOut2 := headway(22) > Passage[2];
GapOut3 := headway(23) > Passage[3];
GapOut4 := headway(24) > Passage[4];
GapOut5 := headway(25) > Passage[5];
GapOut6 := headway(26) > Passage[6];

MinOver1 := t_green(1) >= MinGreen[1];
MinOver2 := t_green(2) >= MinGreen[2];
MinOver3 := t_green(3) >= MinGreen[3];
MinOver4 := t_green(4) >= MinGreen[4];
MinOver5 := t_green(5) >= MinGreen[5];
MinOver6 := t_green(6) >= MinGreen[6];

MaxOut1 := t_green(1) >= MaxGreen[1];
MaxOut2 := t_green(2) >= MaxGreen[2];
MaxOut3 := t_green(3) >= MaxGreen[3];
MaxOut4 := t_green(4) >= MaxGreen[4];
MaxOut5 := t_green(5) >= MaxGreen[5];
MaxOut6 := t_green(6) >= MaxGreen[6];

/***************************************/
/**** CONDITIONS TO CAUSE PHASES ****/
/**** TO CROSS BARRIER TOGETHER *****/
/***************************************/

GapOut26 := GapOut2 AND GapOut6;
MinOver26 := MinOver2 AND MinOver6;
MaxOut26 := MaxOut2 AND MaxOut6.

/**************************************************************************/
/** Ring 1 ********************************************************************/
/**************************************************************************/

SUBROUTINE Ring1;

/**********************************/
/**** RING #1 ACTUATED LOGIC ****/
/**********************************/

/* PEDESTRIAN PHASE */

CallPed12 := presence(29) or occupancy(29);
CallPed10 := presence(27) or occupancy(27);
```

```
CallPed11 := presence(28) or occupancy(28);

IF CallPed12 THEN
        Call12 :=1;
END;

IF CallPed10 THEN
        Call10 :=1;
END;

IF CallPed11 THEN
        Call11 :=1;
END;

/******************************/

IF t_green(1) THEN
        IF (Call2 AND MinOver1 AND (GapOut1 or MaxOut1)) THEN
                sg_red(1);
                start(Phase1ClearTimer);
                NextRing1Phase := 2;
        END;
END;

IF t_green(2) THEN
        IF ((Call3 or Call12) AND MinOver26 AND (GapOut26 or MaxOut26)) THEN
                sg_red(2);
                start(Phase2ClearTimer);
                NextRing1Phase := 3;
                Trace (variable (NextRing1Phase,Call6));                    /*****/
        END;
END;

IF t_green(3) THEN
        IF ((Call4 or Call10) AND (MinOver3 OR (CurrentPhase3TimerAfter >= MinGreen[3])) AND
        ((GapOut3 OR (CurrentPhase3TimerAfter >= MaxGreen[3])) OR MaxOut3)) THEN
                sg_red(3);
                stop(Phase3ClearTimer);
                reset(Phase3ClearTimer);
                start(Phase3ClearTimer);
                NextRing1Phase := 4;
                stop(CurrentPhase3TimerAfter);
                Reset(CurrentPhase3TimerAfter);
        END;
END;

IF t_green(4) THEN
        IF ((Call1 or Call5) AND MinOver4 AND (GapOut4 OR MaxOut4)) THEN
                sg_red(4);
                start(Phase4ClearTimer);
                NextRing1Phase := 1;

        ELSE
```

```
        IF ((Call2) AND MinOver4 AND (GapOut4 OR MaxOut4)) THEN
            sg_red(4);
            start(Phase4ClearTimer);
            NextRing1Phase := 2;
        END;
    END;
END;

/********************************/
/**** RING #1 AMBER TIMERS ****/
/********************************/

IF (Phase1ClearTimer >= tAmber[1] + RedClear[1]) THEN
    IF NextRing1Phase = 2 THEN
        sg_green(2);
    END;
    stop(Phase1ClearTimer);
    reset(Phase1ClearTimer);

END;

IF (Phase2ClearTimer >= tAmber[2] + RedClear[2]) THEN
    IF NextRing1Phase = 3 THEN
        sg_green(3);
        IF (Call12) THEN
            sg_green(12);
            MinGreen[3] := 19;
        ELSE
            MinGreen[3] := 8;
        END;
    END;
    stop(Phase2ClearTimer);
    reset(Phase2ClearTimer);

END;

IF (Phase3ClearTimer >= tAmber[3] + RedClear[3]) THEN
    IF NextRing1Phase = 4 THEN
        sg_green(4);
        IF (Call10) THEN
            sg_green(10);
            MinGreen[4] := 19;

        ELSE
            MinGreen[4] := 8;
        END;
    END;
    stop(Phase3ClearTimer);
    reset(Phase3ClearTimer);
END;

IF (Phase4ClearTimer >= tAmber[4] + RedClear[4]) THEN
    IF NextRing1Phase = 1 THEN
```

```
            sg_green(1);
            sg_green(5);

        /*************** Added to Bypass Left Turn Phases ******************/
        ELSE
            IF NextRing1Phase = 2 THEN
                sg_green(2);
                sg_green(6);
                IF (Call11) THEN
                    sg_green(11);
                    MinGreen[2] := 19;
                    MinGreen[6] := 19;
                ELSE
                    MinGreen[2] := 10;
                    MinGreen[6] := 10;
                END;
            END;
        END;
        /*************** Added to Bypass Left Turn Phases ******************/

        IF FirstAfterDwell = 1 THEN
            cycle := cycle +1;
        END;
        stop(Phase4ClearTimer);
        reset(Phase4ClearTimer);
END;

/* PEDESTRIAN GREEN PHASE END  */

IF (t_green(10) >= PedGreen[2]) THEN
        sg_red(10);
        Call10 := 0;
        start(Ped10ClearTimer);
END;

IF (t_green(12) >= PedGreen[4]) THEN
        sg_red(12);
        Call12 := 0;
        start(Ped12ClearTimer);
END;

/*******************************/
/******* AMBER TIMERS ********/
/*******************************/

IF (Ped12ClearTimer >= PedClr[1]) THEN
        stop(Ped12ClearTimer);
        reset(Ped12ClearTimer);
END;

IF (Ped10ClearTimer >= PedClr[1]) THEN
        stop(Ped10ClearTimer);
        reset(Ped10ClearTimer);
```

```
END.

/****************************************************************************/
/** Ring 2 ******************************************************************/
/****************************************************************************/

SUBROUTINE Ring2;

/**********************************/
/**** RING #2 ACTUATED LOGIC ****/
/**********************************/

IF t_green(5) THEN
        IF ((Call6 or Call11) AND MinOver5 AND (GapOut5 OR MaxOut5)) THEN
                sg_red(5);
                start(Phase5ClearTimer);
                NextRing2Phase := 6;
        END;
END;

IF t_green(6) THEN
        IF ((Call3 or Call12) AND MinOver26 AND (GapOut26 OR MaxOut26)) THEN
                sg_red(6);
                start(Phase6ClearTimer);
                NextRing1Phase := 3;
        END;
END;

/********************************/
/**** RING #2 AMBER TIMERS ****/
/********************************/

IF (Phase5ClearTimer = tAmber[5] + RedClear[5]) THEN
        IF NextRing2Phase = 6 THEN
                sg_green(6);
                IF (Call11) THEN
                        sg_green(11);
                        MinGreen[6] := 19;
                        MinGreen[2] := 19;
                ELSE
                        MinGreen[6] := 10;
                        MinGreen[2] := 10;
                END;
        END;
        stop(Phase5ClearTimer);
        reset(Phase5ClearTimer);

END;

IF (Phase6ClearTimer = tAmber[6] + RedClear[6]) THEN
        IF NextRing1Phase = 3 THEN
                sg_green(3);
                IF (Call12) THEN
```

```
                sg_green(12);
                MinGreen[3] := 19;
            ELSE
                MinGreen[3] := 8;
            END;
        END;
        stop(Phase6ClearTimer);
        reset(Phase6ClearTimer);
END;

/* PEDESTRIAN GREEN PHASE END  */

IF (t_green(11) >= PedGreen[3]) THEN
        sg_red(11);
        Call11 := 0;
        start(Ped11ClearTimer);
END;

/*******************************/
/******* AMBER TIMERS ********/
/*******************************/

IF (Ped11ClearTimer >= PedClr[1]) THEN
        stop(Ped11ClearTimer);
        reset(Ped11ClearTimer);
END.

/***************************************************************************/
/** Preemption ************************************************************/
/***************************************************************************/

SUBROUTINE Preemption;

IF CurrentPhaseRing1=0 THEN

        /************** Check Current vehicle phase for Ring 1  ************/

        IF T_green(1) THEN
                CurrentPhaseRing1:=1;
        ELSE
                IF T_green(2) THEN
                        CurrentPhaseRing1:=2;
                ELSE
                        IF T_green(3)  THEN
                                CurrentPhaseRing1:=3;
                        ELSE
                                IF T_green(4) THEN
                                        CurrentPhaseRing1:=4;
                                ELSE
                                        CurrentPhaseRing1:=100;
                                END;
                        END;
                END;
```

```
        END;

        /************** Check Current vehicle phase for Ring 2 ************/

        IF T_green(5) THEN
                CurrentPhaseRing2:=5;
        ELSE
                IF T_green(6) THEN
                        CurrentPhaseRing2:=6;
                ELSE
                        CurrentPhaseRing2:=100;
                END;
        END;

        /************** Check Current pedestrian phase for Ring 1 **********/

                IF ((Ped10ClearTimer < SelPedClr[1]) or T_green(10)) THEN
                        CurrentPedPhaseRing1:=10;
                ELSE
                        IF ((Ped12ClearTimer < SelPedClr[1]) or T_green(12)) THEN
                                CurrentPedPhaseRing1:=12;
                        ELSE
                                CurrentPedPhaseRing1:=100;
                        END;
                END;

        /************** Check Current pedestrian phase for Ring 2 **********/

        IF ((Ped11ClearTimer < SelPedClr[1]) or T_green(11)) THEN
                CurrentPedPhaseRing2:=11;
        ELSE
                        CurrentPedPhaseRing2:=100;
        END;
END;

/**** Terminate Current Phase and Start Track Clearance Phase ***************/

IF (TrackClearStart=0) THEN

        /************** Phase 1 ************************/
        IF ((CurrentPhaseRing1 = 1) AND (T_green(CurrentPhaseRing1)>= PreempMin[1])) THEN
                sg_red(1);
                start(CurrentClear1Timer);
                Check := 1;
        END;

        IF (CurrentClear1Timer = tAmber[1] + RedClear[1]) THEN
                sg_green(3);
                TrackClearStart:=1;
                start(CurrentPhase3Timer);
                stop(CurrentClear1Timer);
                reset(CurrentClear1Timer);
        END;
```

```
/************** Phase 5 ************************/
IF ((CurrentPhaseRing2 = 5) AND (T_green(CurrentPhaseRing2)>= PreempMin[1])) THEN
        sg_red(5);
        start(CurrentClear5Timer);
        Check := 5;
END;

IF (CurrentClear5Timer = tAmber[5] + RedClear[5]) THEN
        sg_green(3);
        TrackClearStart:=1;
        start(CurrentPhase3Timer);
        stop(CurrentClear5Timer);
        reset(CurrentClear5Timer);
END;

/************** Phase 2 ************************/
IF ((CurrentPhaseRing1 = 2) AND (T_green(CurrentPhaseRing1) >= PreempMin[1]) THEN
        sg_red(2);
        start(CurrentClear2Timer);
        Check := 22;
        Trace(variable (Check));
ELSE
        IF ((CurrentPhaseRing1 = 2) AND (T_green(CurrentPhaseRing1) >= PreempMin[1]))
THEN
                sg_red(2);
                start(CurrentClear2Timer);
                Check := 22;
                Trace(variable (Check));
        END;
END;

IF (CurrentClear2Timer = tAmber[2] + RedClear[2]) THEN
        sg_green(3);
        TrackClearStart:=1;
        start(CurrentPhase3Timer);
        stop(CurrentClear2Timer);
        reset(CurrentClear2Timer);
END;

/************** Phase 6 ************************/
IF ((CurrentPhaseRing2 = 6) AND (CurrentPedPhaseRing2 = 11) AND
T_green(CurrentPedPhaseRing2)) THEN
        sg_red(11);
        start(Ped11ClearTimer);
        Check := 6;
END;

IF ((CurrentPhaseRing2 = 6) AND (T_green(CurrentPhaseRing2) >= PreempMin[1]) AND
(CurrentPedPhaseRing2 = 11) AND (Ped11ClearTimer >= 0)) THEN
        sg_red(6);
        start(CurrentClear6Timer);
        Check := 66;
```

```
        ELSE
                IF ((CurrentPhaseRing2 = 6) AND (T_green(CurrentPhaseRing2) >= PreempMin[1]))
THEN
                        sg_red(6);
                        Start(CurrentClear6Timer);
                        Check := 66;
                END;
        END;

        IF (CurrentClear6Timer = tAmber[6] + RedClear[6]) THEN
                sg_green(3);
                TrackClearStart:=1;
                start(CurrentPhase3Timer);
                stop(CurrentClear6Timer);
                stop(Ped11ClearTimer);
                reset(CurrentClear6Timer);
        END;

        /************** Phase 4 ************************/
        IF ((CurrentPhaseRing1 = 4) AND (CurrentPedPhaseRing1 = 10) AND
T_green(CurrentPedPhaseRing1)) THEN
                sg_red(10);
                start(Ped10ClearTimer);
                Check := 4;
        END;

        IF ((CurrentPhaseRing1 = 4) AND (T_green(CurrentPhaseRing1) >= PreempMin[1]) AND
        (CurrentPedPhaseRing1 = 10) AND (Ped10ClearTimer >= 0)) THEN
                sg_red(4);
                start(CurrentClear4Timer);
                Check := 44;
        ELSE
                IF ((CurrentPhaseRing1 = 4) AND (T_green(CurrentPhaseRing1) >= PreempMin[1]))
THEN
                        sg_red(4);
                        start(CurrentClear4Timer);
                        Check := 44;
                END;
        END;

        IF (CurrentClear4Timer = tAmber[4] + RedClear[4]) THEN
                sg_green(3);
                TrackClearStart:=1;
                start(CurrentPhase3Timer);
                stop(CurrentClear4Timer);
                stop(Ped10ClearTimer);
                reset(CurrentClear4Timer);
                reset(Ped10ClearTimer);
        END;

        /************** Phase 3 ************************/
        IF ((CurrentPhaseRing1 = 3) AND (CurrentPedPhaseRing1 = 12) AND
T_green(CurrentPedPhaseRing1)) THEN
```

```
            sg_red(12);
            start(Ped12ClearTimer);
            Check := 3;
            Trace(variable (Check));
      END;

      IF ((CurrentPhaseRing1 = 3) AND (CurrentPedPhaseRing1 = 12) AND (Ped12ClearTimer >= 0))
THEN
            start(CurrentPhase3Timer);
            TrackClearStart:=1;
            Check := 3;
            Trace(variable (Check));
      ELSE
            IF (CurrentPhaseRing1 = 3) THEN
                  sg_red(12);
                  start(CurrentPhase3Timer);
                  TrackClearStart:=1;
                  Check := 3;
            END;
      END;

      /************** Phase red for Ring 1 *****************************/
      /*********** T_stop is the time since the signal was green. ************/

      IF ((CurrentPhaseRing1 = 100)/* AND (CurrentPedPhaseRing1 = 100)*/) THEN
            IF (T_stop(1) = 6) OR (T_stop(2) = 6) OR (T_stop(3) <= 6) OR (T_stop(4) = 6) OR
            (T_stop(5) = 6) OR (T_stop(6) = 6) THEN
                  sg_green(3);
                  stop(Phase3ClearTimer);
                  reset(Phase3ClearTimer);
                  TrackClearStart:=1;
                  start(CurrentPhase3Timer);
                  Check := 100;
            END;
      END;

      /************** Phase red for Ring 2 *****************************/
      /*********** T_stop is the time since the signal was green. ************/

      IF ((CurrentPhaseRing2 = 100)/* AND (CurrentPedPhaseRing2 = 100)*/) THEN
            IF (T_stop(1) = 6) OR (T_stop(2) = 6) OR (T_stop(3) <= 6) OR (T_stop(4) = 6) OR
            (T_stop(5) = 6) OR (T_stop(6) = 6) THEN
                  sg_green(3);
                  stop(Phase3ClearTimer);
                  reset(Phase3ClearTimer);
                  TrackClearStart:=1;
                  start(CurrentPhase3Timer);
                  Check := 100;
            END;
      END;

END;
```

```
/**** Start Dwell ************************************************************/

IF ((DwellPoint = 1) OR (CurrentPhase3Timer = TrackClrTime[1])) THEN

        Call5 := presence(25) or occupancy(25) OR DwellRECALL[5];
        Call6 := presence(26) or occupancy(26) OR DwellRECALL[6];

        GapOut5 := headway(25) > Passage[5];
        GapOut6 := headway(26) > Passage[6];

        MinOver5 := t_green(5) >= MinDwellGreen[5];
        MinOver6 := t_green(6) >= MinDwellGreen[6];

        MaxOut5 := t_green(5) >= MaxDwellGreen[5];
        MaxOut6 := t_green(6) >= MaxDwellGreen[6];

        CallPed11 := presence(28) or occupancy(28);
                IF CallPed11 THEN
                        Call11 :=1;
                END;

        IF (StartDwell=0) THEN
                /************** End Track Clearance ************************/
                IF  (CurrentPhase3Timer= TrackClrTime[1]) THEN
                        sg_red(3);
                        start(ClearTrack);
                        stop(CurrentPhase3Timer);
                        reset(CurrentPhase3Timer);
                        DwellPoint := 1;
                END;

                /************* Start Dwell *********************************/
                IF (ClearTrack = tAmber[3] + RedClear[3]) THEN
                        sg_green(2);
                        stop(ClearTrack);
                        reset(ClearTrack);
                        StartDwell:=1;
                        sg_green(5);
                END;
        END;

        IF (Call5 AND MinOver6 AND (GapOut6 OR MaxOut6)) THEN
                sg_red(6);
                start(Phase6ClearTimer);
        END;

        IF (Call6 AND MinOver5 AND (GapOut5 OR MaxOut5)) THEN
                sg_red(5);
                start(Phase5ClearTimer);
        END;

        IF (t_green(11) = DwellPedGreen[2]) THEN
                sg_red(11);
```

```
			start(Ped11ClearTimer);
		END;

		IF (Ped11ClearTimer = PedClr[1]) THEN
			stop(Ped11ClearTimer);
			reset(Ped11ClearTimer);
		END;

		/*****************************/
		/******* AMBER TIMERS ********/
		/*****************************/

		IF (Phase6ClearTimer = tAmber[6] + RedClear[6]) THEN
			sg_green(5);
			stop(Phase6ClearTimer);
			reset(Phase6ClearTimer);
		END;

		IF (Phase5ClearTimer = tAmber[5] + RedClear[5]) THEN
			sg_green(6);
			IF (Call11) THEN
				sg_green(11);
				MinGreen[6] := 19;
				MinGreen[2] := 19;
			ELSE
				MinGreen[6] := 10;
				MinGreen[2] := 10;
			END;
			stop(Phase5ClearTimer);
			reset(Phase5ClearTimer);
		END;
END.

/***************************************************************************/
/** Release Preemption ****************************************************/
/***************************************************************************/

SUBROUTINE ReleasePreemption;

/** Check Current Phase at the end of Preemption **********************************/
IF (CurrentPhaseAfter1 = 0) THEN
	CurrentPhaseAfter1:=2;

	IF T_green(6) THEN
		CurrentPhaseAfter2:=6;
	ELSE
		IF T_green(5) THEN
			CurrentPhaseAfter2:=5;
		ELSE
			CurrentPhaseAfter2:=100;
		END;
	END;
```

```
END;

/** Terminate Current Phase ****************************************************/
CallPed12 := presence(29) or occupancy(29);
        IF CallPed12 THEN
                Call12 :=1;
        END;

IF (EndPreemption=0) THEN

        /**** For the case of Pedestrian phase is Green ******************/
        IF (Oneperform = 0) THEN
                Oneperform := 1;
                IF (T_green(11)) THEN
                        sg_red(11);
                        start(Ped11ClearTimer);
                        Check := 11;
                END;
        END;

        /************** Phase 5  ************************/
        IF ((CurrentPhaseAfter2 = 5) AND (T_green(CurrentPhaseAfter2) >= PreempMin[1]) ) THEN
                sg_red(2);
                sg_red(5);
                start(CurrentClear5TimerAfter);
                Check := 25;
                Trace (variable (Check));
        END;
        IF (CurrentClear5TimerAfter = tAmber[5] + RedClear[5]) THEN
                sg_green(3);
                IF (Call12) THEN
                        sg_green(12);
                        MinGreen[3] := 19;
                ELSE
                        MinGreen[3] := 8;
                END;
                EndPreemption:=1;
                start(CurrentPhase3TimerAfter);
                stop(CurrentClear5TimerAfter);
                reset(CurrentClear5TimerAfter);
        END;

        /************** Phase 6 ************************/
        IF ((CurrentPhaseAfter2 = 6) AND (T_green(CurrentPhaseAfter2)>= PreempMin[1]) AND
        ((Ped11ClearTimer = 0) OR (Ped11ClearTimer >= RetPedClr[1]))) THEN
                sg_red(2);
                sg_red(6);
                start(CurrentClear2TimerAfter);
                Check := 26;
                Trace (variable (Check));
        END;
        IF (CurrentClear2TimerAfter = tAmber[2] + RedClear[2]) THEN
                sg_green(3);
```

```
                IF (Call12) THEN
                        sg_green(12);
                        MinGreen[3] := 19;
                ELSE
                        MinGreen[3] := 8;
                END;
                EndPreemption:=1;
                start(CurrentPhase3TimerAfter);
                stop(CurrentClear2TimerAfter);
                reset(CurrentClear2TimerAfter);
        END;

        /************** Phase red ***********************/
    IF ((CurrentPhaseAfter2 = 100) AND ((Phase5ClearTimer >= tAmber[5] + RedClear[5]) or
    (Phase6ClearTimer >= tAmber[6] + RedClear[6]))) THEN
                sg_red(2);
                stop(Phase5ClearTimer);
                reset(Phase5ClearTimer);
                stop(Phase6ClearTimer);
                reset(Phase6ClearTimer);
                start(CurrentClear2TimerAfter);
                Check:=100;
                Trace (variable (Check));
        END;
    IF (Phase6ClearTimer = tAmber[6] + RedClear[6]) THEN
                sg_green(3);
                IF (Call12) THEN
                        sg_green(12);
                        MinGreen[3] := 19;
                ELSE
                        MinGreen[3] := 8;
                END;
                EndPreemption:= 1;
                start(CurrentPhase3TimerAfter);
        END;
END.

/*****************************/
/**** BEGIN MAIN SECTION ****/
/*****************************/
Prese := presence(69) or occupancy(69) or presence(70) or occupancy(70) or presence(71) or
occupancy(71) or presence(72) or occupancy(72);
        IF Prese THEN
                GOSUB Preemption;
                PreemptionOn:=1;
        ELSE
                IF ((PreemptionOn=1) AND (EndPreemption=0)) THEN
                        GOSUB ReleasePreemption;
                        Trace (variable (PreemptionOn));
                ELSE
                        IF (EndPreemption = 0) OR (cycle = 3) THEN
                                GOSUB Compute_Conditionals;
                                GOSUB Ring1;
```

```
                GOSUB Ring2;
            ELSE
                GOSUB CorrectionCompute_Conditionals;
                GOSUB Ring1;
                GOSUB Ring2;
            END;
        END;
END.
```

VITA

Jonathan Michael Tydlacka

112 Oak Run, College Station, TX 77845

jtydlacka@neo.tamu.edu (979) 764-2774

Education B.S., Civil Engineering, Texas A & M University (expected Dec. 2002)

- Systems Safety Engineering Certificate (expected Dec. 2002)
- Engineering Scholars Program participant, 1999–present
- TTI Summer Undergraduate Research Fellow, 2002

Academic Information

Computer Skills

- VISSIM
- Terramodel
- Microsoft Office
- Matlab
- HEC-1, HEC-2
- Maple

Related Coursework

- Traffic Engineering
- Design Optimization
- Systems Safety Engineering
- Pavement Design
- Urban Planning
- Human Factors

Academic Interests

- Plan to pursue a Master of Science Degree in Civil Engineering at Texas A&M University beginning in spring 2003
- Areas of Interest include
  - Traffic Operations
  - Micro-simulation Modeling
  - Intelligent Transportation Systems

Awards, Activities & Interests

- 2000–2002 Truman R. Jones '43 Memorial Endowed Scholarship

- American Society of Civil Engineers, Student Member, 1999-present
- Chi Epsilon Civil Engineering Honor Society, 2000-present
- Tau Beta Pi Engineering Honor Society, Active Member, 2000-present
- National Society of Collegiate Scholars, Active Member, 2000-present, Officer, 2001-2002
- Golden Key Honor Society, Active Member, 2000-present
- St Mary's Catholic Church, Hospitality Coordinator and Head Usher
- Experienced Long Distance Runner having completed many marathon and ultra-marathon races